

# Fuel Cell Technologies Program

U.S. DEPARTMENT OF  
**ENERGY** | Energy Efficiency &  
Renewable Energy



## DOE Hydrogen & Fuel Cell Overview

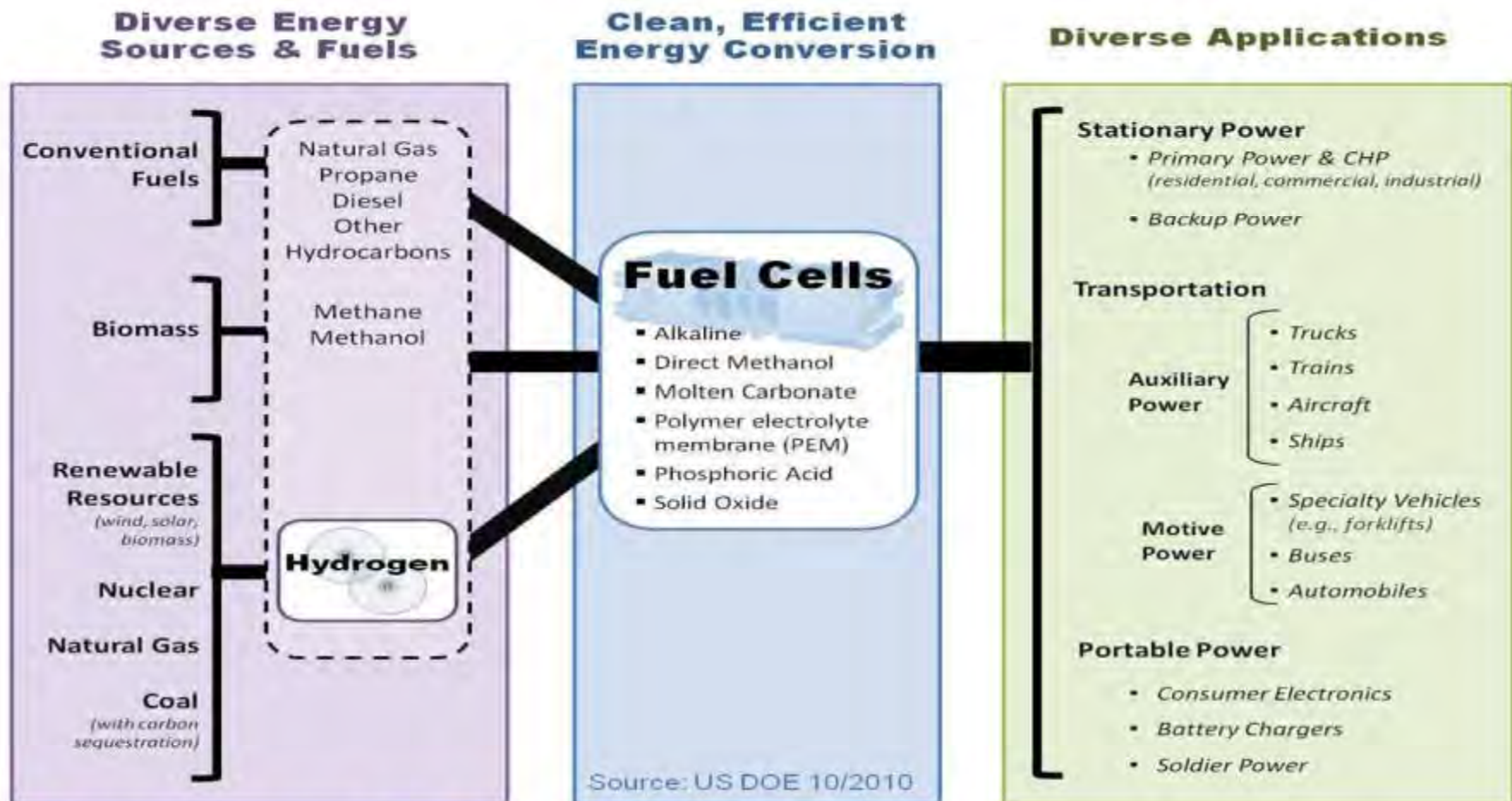
January 13, 2011

**Dr. Sunita Satyapal**

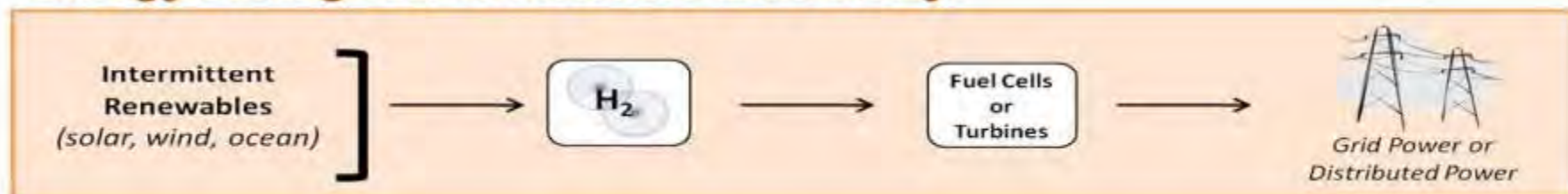
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# Fuel Cells for Diverse Applications



## Energy Storage for Renewable Electricity





# Fuel Cells - *Where are we today?*

Fuel Cells for Stationary Power, Auxiliary Power, and Specialty Vehicles

The largest markets for fuel cells today are in stationary power, portable power, auxiliary power units, and forklifts.

*~75,000 fuel cells have been shipped worldwide.*

*~24,000 fuel cells shipped in 2009 (> 40% increase over 2008).*

*Fuel cells can be a cost-competitive option for critical-load facilities, backup power, and forklifts.*



Fuel Cells for Transportation

In the U.S., there are currently:

*> 200 fuel cell vehicles*

*~ 20 active fuel cell buses*

*~ 60 fueling stations*

Sept. 2009: Auto manufacturers from around the world signed a letter of understanding supporting fuel cell vehicles in anticipation of widespread commercialization, beginning in 2015.



Production & Delivery of Hydrogen

In the U.S., there are currently:

*~9 million metric tons of H<sub>2</sub> produced annually*

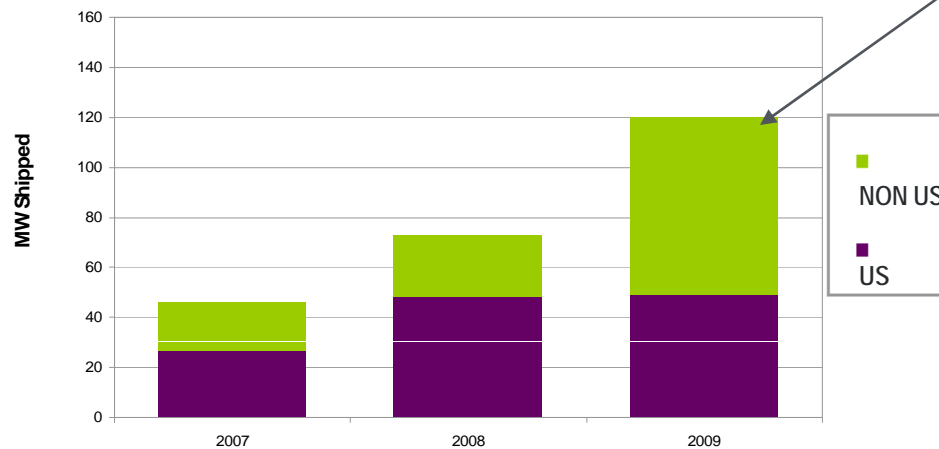
*> 1200 miles of H<sub>2</sub> pipelines*



Source: US DOE 09/2010

# Global competition is increasing

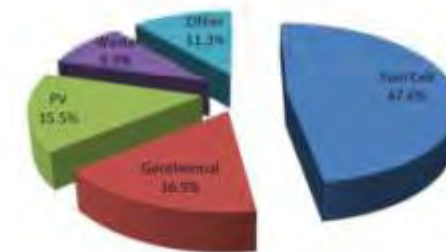
Global MWs Shipped, by US Companies and Non-US Companies



Significant increase in MW shipped by non-US companies in just 1 year  
>40% market growth in just one year

Example: Seoul's Renewable energy generation plan includes ~  
**48% fuel cells**

Anticipated Renewable Energy Generation in Seoul, Korea by 2030



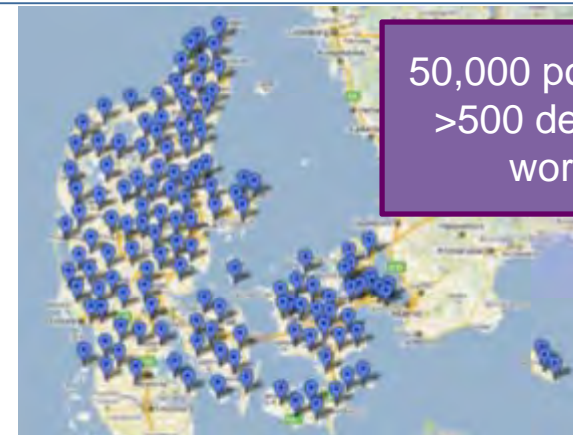
Source: Municipal Government of Seoul

## Preliminary market analysis

### International Landscape favors H<sub>2</sub> & Fuel Cells

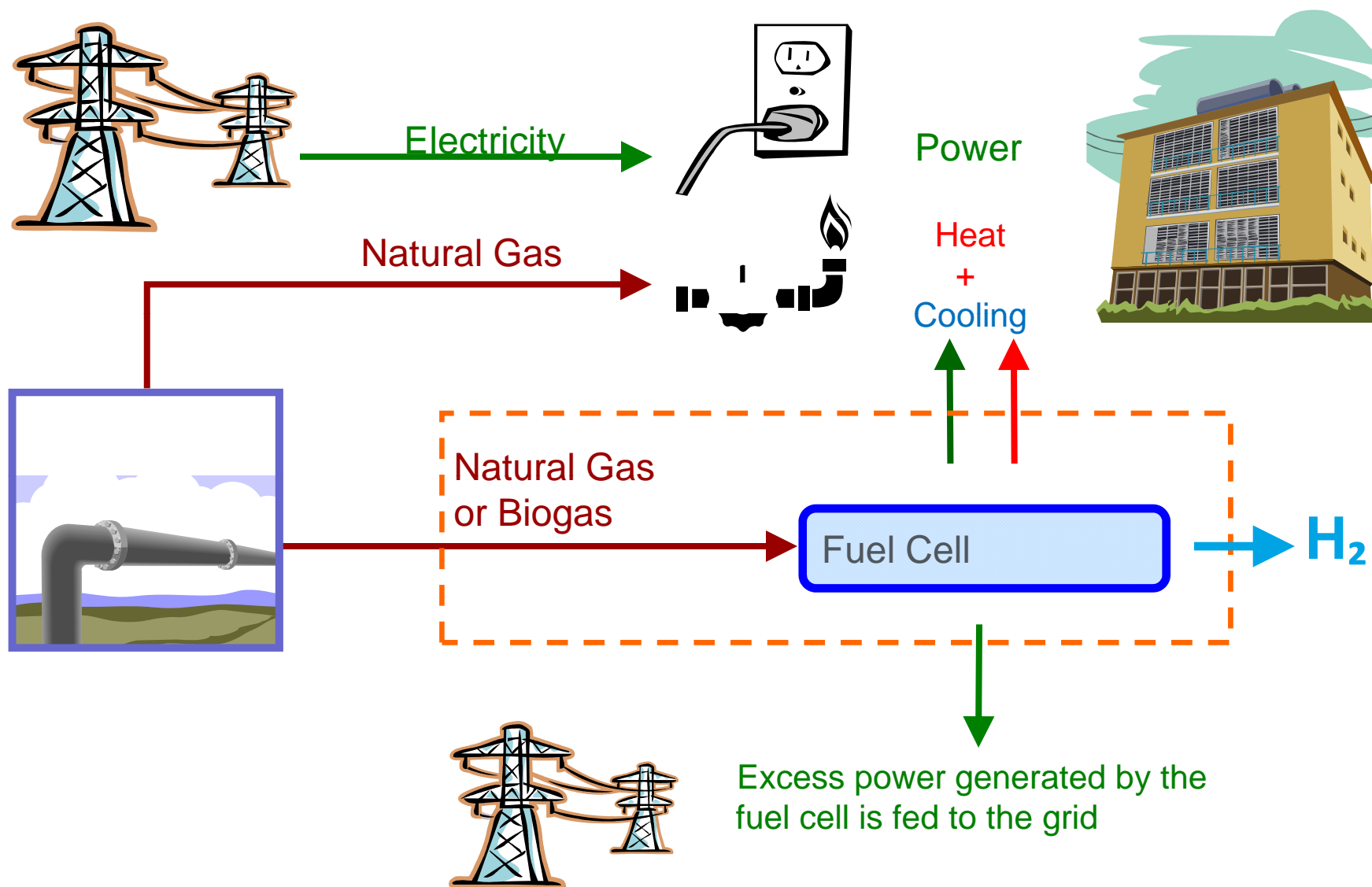
- Germany (>\$1.2B; 1,000 H<sub>2</sub> stations)
- European Commission (>\$1.2B, 2008-2013)
- Japan (2M vehicles, 1,000 H<sub>2</sub> stations by 2025)
- South Korea (plans to produce 20% of world shipments & create 560,000 jobs in Korea)
- China (thousands of small units; 70 FCVs, buses, 100 shuttles at World Expo, Olympics)
- Subsidies for jobs, manufacturing, deployments (e.g. South Africa)

Example: Denmark Backup Power Deployments



50,000 potential sites  
>500 deployments worldwide

# Overview of Combined Heat+Power

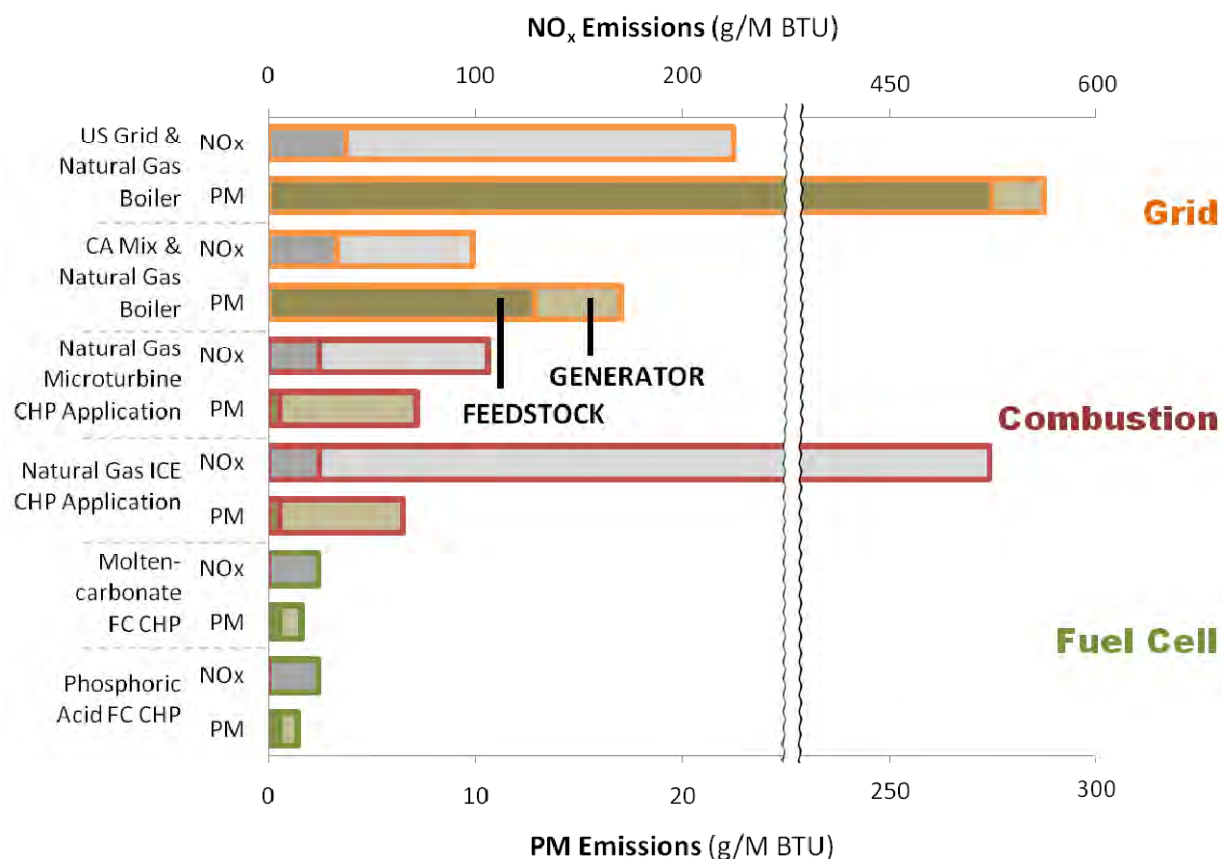


# Biogas Benefits: Preliminary Analysis

*Stationary fuel cells offer significant reductions in criteria pollutant emissions.*

## Criteria Pollutant Emissions (g/M BTU)

### NO<sub>x</sub> and PM Emissions from CHP and Competing Technologies



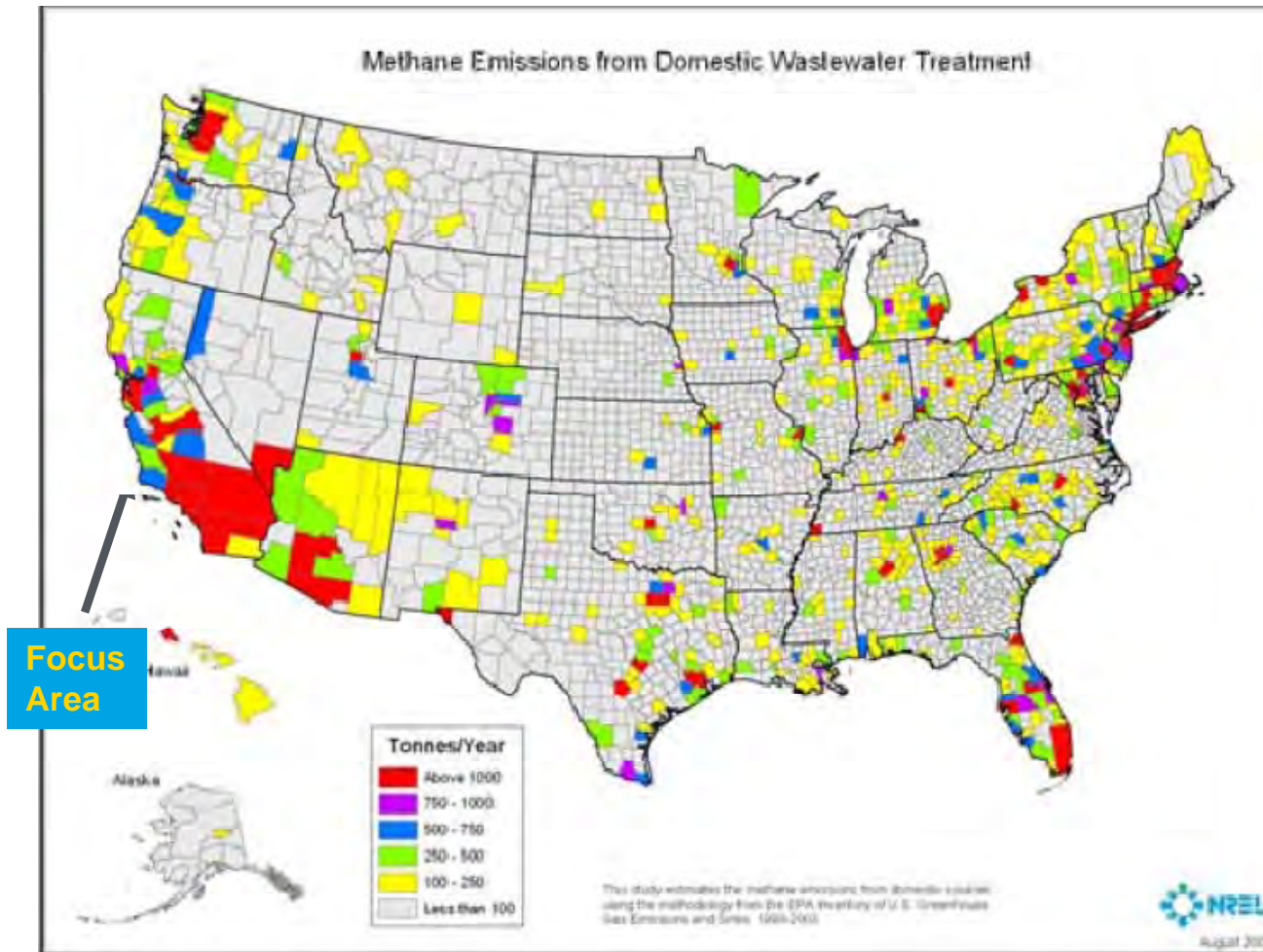
Criteria Pollutant Emissions from Generating Heat and Power. *Fuel cells emit about 75 – 90% less NO<sub>x</sub> and about 75 – 80% less particulate matter (PM) than other CHP technologies, on a life-cycle basis. In addition, similar to other CHP technologies, fuel cells can provide more than 50% reduction in CO<sub>2</sub> emissions, when compared with the national grid.*

Source: US DOE 1/2011



# Biogas Resource Example: Methane from Waste Water Treatment

*Biogas from waste water treatment plants is ideally located near urban centers to supply hydrogen for fuel cell vehicles.*



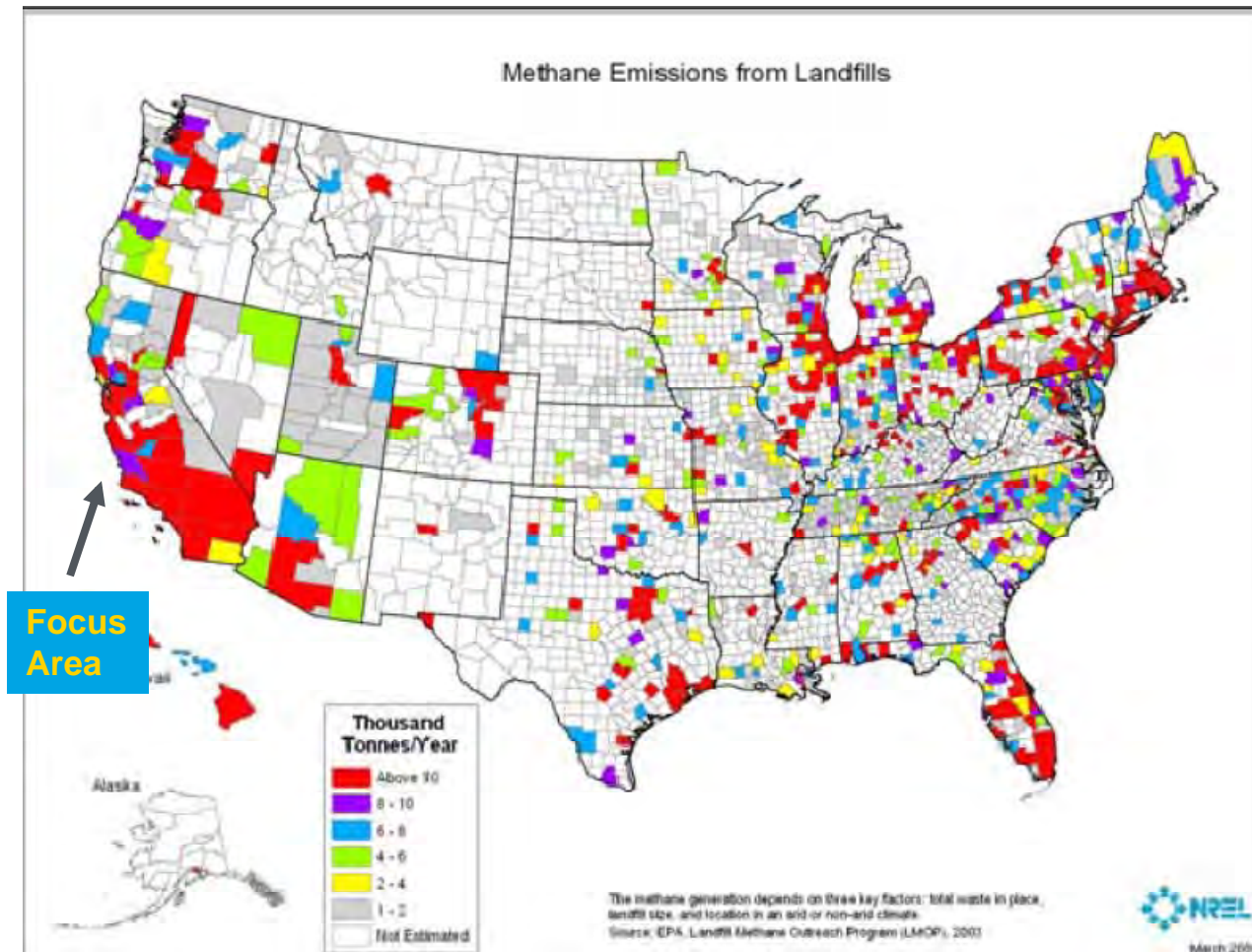
Source: NREL report *A Geographic Perspective on Current Biomass Resource Availability in the United States*, 2005

- 500,000 MT per year of methane available from waste water treatment plants in U.S.
- Majority of resource located near urban centers.
- If ~50% of the bio-methane was available, ~340,000 kg/day of renewable hydrogen could be produced from steam methane reforming
- Renewable hydrogen is enough to fuel ~340,000 fuel cell vehicles per day.



# Biogas Resource Example: Methane from Landfills

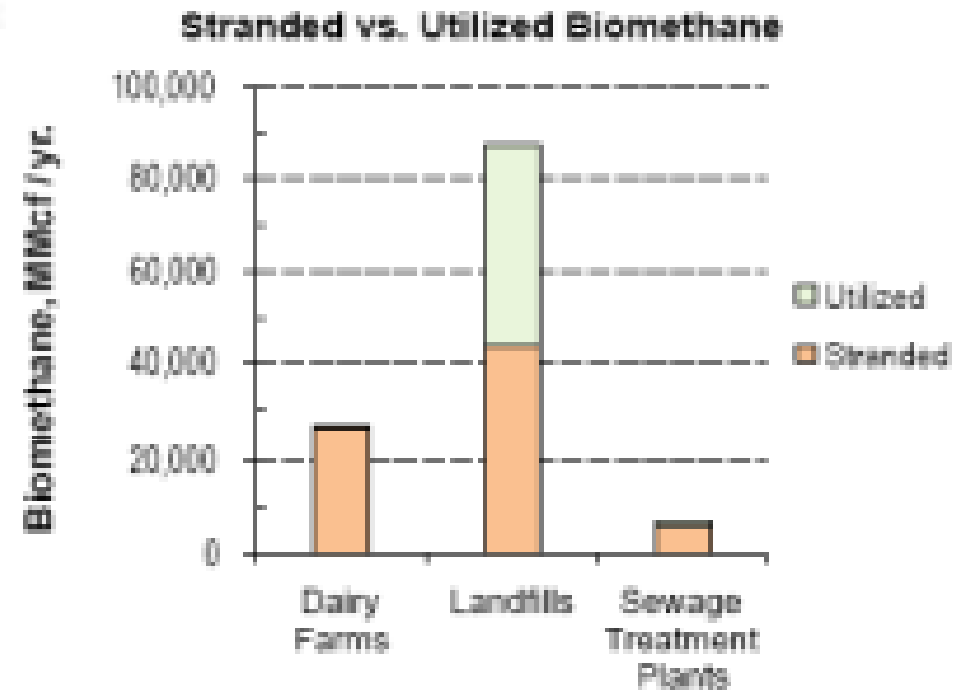
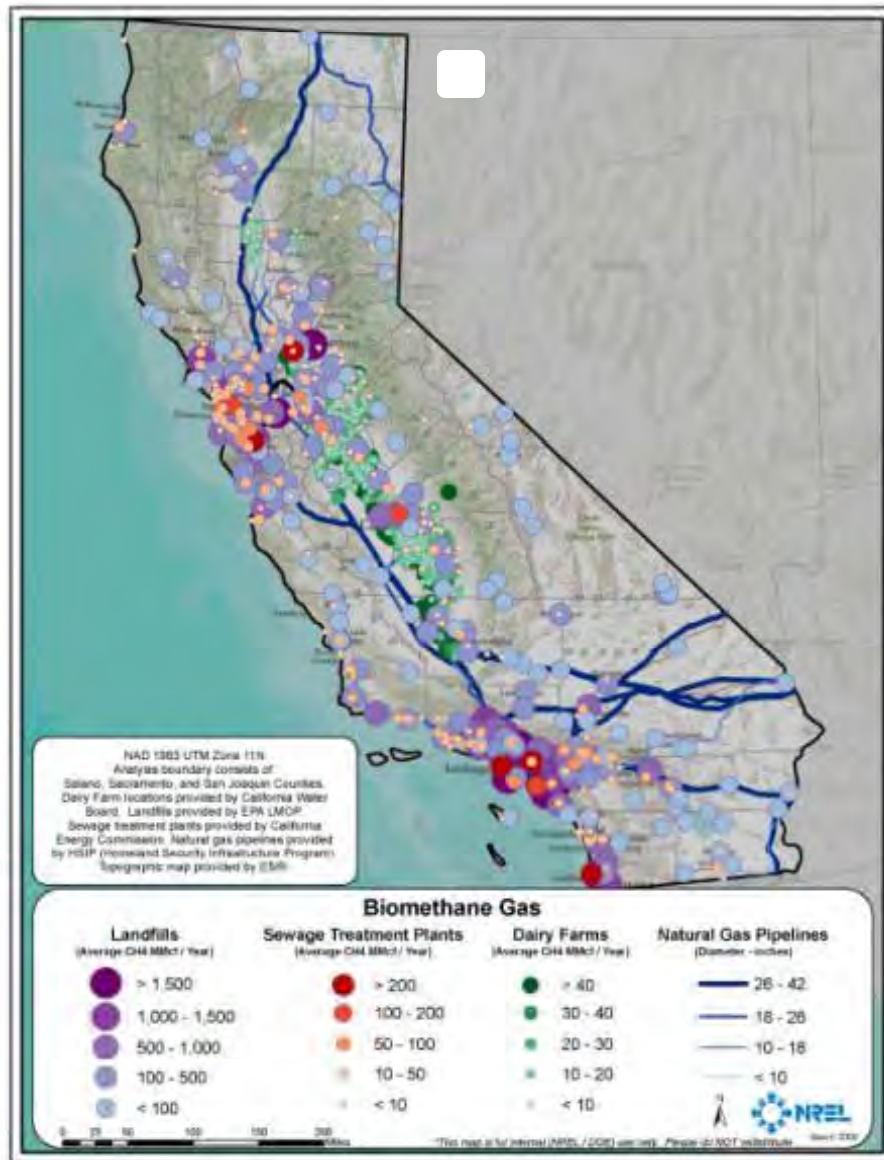
*Biogas from landfills is located near large urban centers and could provide enough renewable resource to fuel ~8 million fuel cell vehicles per day.*



- 12.4 million MT per year of methane available from landfills in U.S.
- Majority of resource located near urban centers.
- If 50% of the bio-methane was available, ~8 million kg/day of renewable hydrogen could be produced from steam methane reforming.
- Renewable hydrogen is enough to fuel ~8 million fuel cell vehicles per day.

Source: NREL report *A Geographic Perspective on Current Biomass Resource Availability in the United States*, 2005

# California Example: Potential Sources of Biogas



Source: NREL

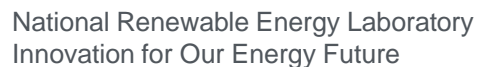
**Example:**

**Landfills offer ~1.6 M tons/yr of bio-methane.**

- Only ~50% of the landfill biomethane is used



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- 300 tons/day
- 19,200 kW

## Urban wood waste is an abundant feedstock around the US



*Demonstrations are essential for validating the performance of technologies in integrated systems, under real-world conditions.*

## RECENT PROGRESS

### Vehicles & Infrastructure

- 152 fuel cell vehicles and 24 hydrogen fueling stations
- Over 2.8 million miles traveled
- Over 114 thousand total vehicle hours driven
- 2,500 hours (nearly 75K miles) durability
- Fuel cell efficiency 53-59%
- Vehicle Range: ~196 – 254 miles (independently also validated 430 mile range)

### Buses

- DOE is evaluating real-world bus fleet data (DOT collaboration)
- H<sub>2</sub> fuel cell buses have a 41% to 132% better fuel economy compared to diesel & CNG buses

### Forklifts

- Over 18,000 refuelings at Defense Logistics Agency site

### Recovery Act

- DOE (NREL) is collecting operating data from deployments for an industry-wide report



Landfills generate landfill gas (LFG) from active microorganisms interacting with the waste. Through available efficient reformation processes, this gas can easily be converted into hydrogen and used to provide energy or fuel, effectively turning trash into power.



BMW Manufacturing site.  
Courtesy of Waste Management World

Source: US DOE 12/2010

## Project Goals

- To show that LFG, cleaned up **and reformed**, can be used to power material handling equipment (MHE)

## Next Steps

- Gas analysis & MHE performance data.
- Comparing LFG-produced hydrogen and delivered hydrogen.
- “Real world” evaluation and testing of equipment.

## Landfill Gas to Hydrogen Benefits

- ✓ Reduced emissions
- ✓ Additional power supply
- ✓ Additional vehicle fuel source

# Market Transformation activities seek to overcome barriers to commercialization

## BARRIERS

### Market/Industry

Lack of domestic supply base and high volume manufacturing.  
Estimated backlog > 100 MW

Low-volume capital cost is >2-3x of targets

Policies — e.g., many early adopters not eligible for \$3,000/kW tax credit

### Delivery Infrastructure

Significant investment needed—  
~\$55B gov't funding required over 15 years for ~5.5M vehicles (\$~10B for stations)\*

### Codes and Standards

Complicated permitting process.  
44,000 jurisdictions

H<sub>2</sub>-specific codes needed; only 60% of component standards specified in NFPA codes and standards are complete

Need for domestic and international consistency

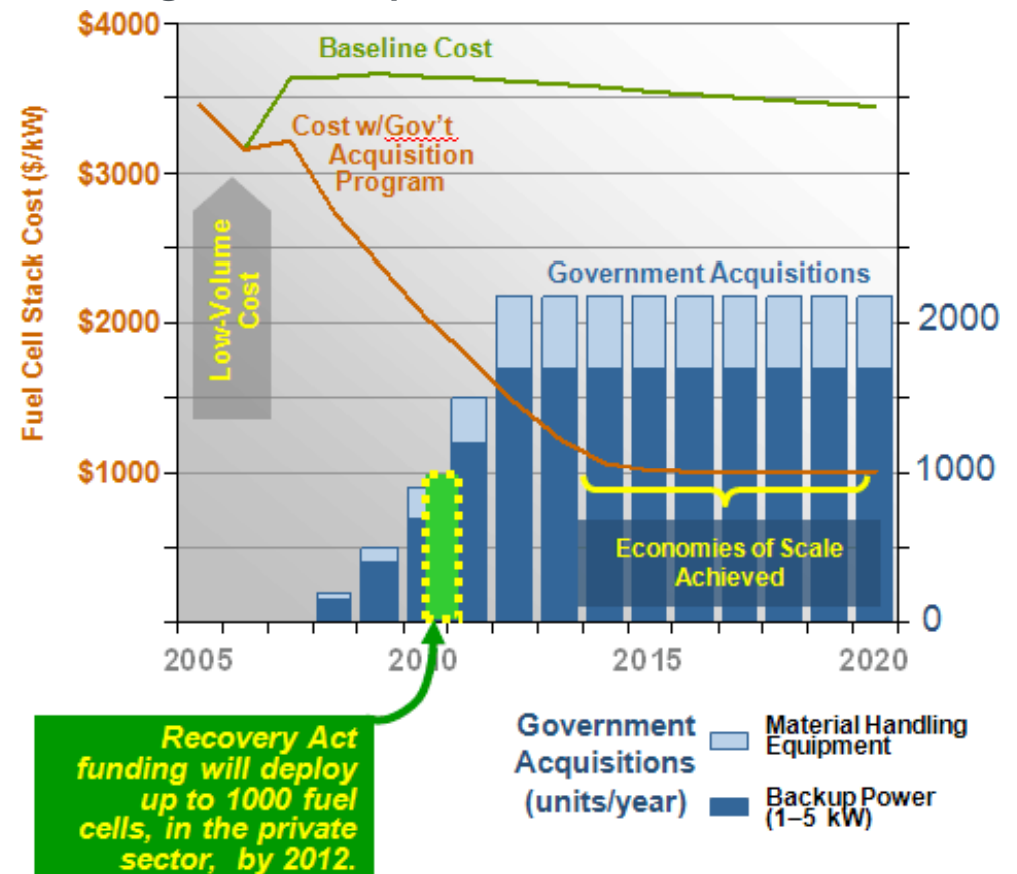
### Education

In spite of >7,000 teachers trained and online tools averaging 300-500 visits/month, negative public perception and safety concerns remain.

\*2008 National Academies Study, *Transitions to Alternative Transportation Technologies—A Focus on Hydrogen*

## ADDRESSING BARRIERS Example:

*A government acquisition program could have a significant impact on fuel cell stack costs*



Source: David Greene, ORNL; K.G. Duleep, Energy and Environmental Analysis, Inc., *Bootstrapping a Sustainable North American PEM Fuel Cell Industry: Could a Federal Acquisition Program Make a Difference?*, 2008.

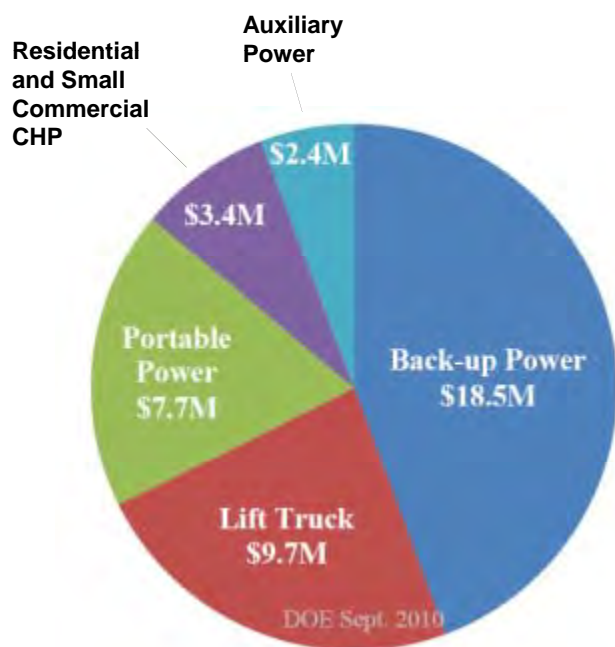


# Recovery Act Funding for Fuel Cells

*More than \$40 million from the 2009 American Recovery and Reinvestment Act to fund 12 projects to deploy up to 1,000 fuel cells*

FROM the LABORATORY to  
DEPLOYMENT:

*DOE funding has supported R&D  
by all of the fuel cell suppliers  
involved in these projects.*



Approximately \$54 million in cost-share funding from industry participants—for a total of about \$96 million.

COMPANY	AWARD	APPLICATION
Delphi Automotive	\$2.4 M	Auxiliary Power
FedEx Freight East	\$1.3 M	Lift Truck
GENCO	\$6.1 M	Lift Truck
Jadoo Power	\$2.2 M	Portable
MTI MicroFuel Cells	\$3.0 M	Portable
Nuvera Fuel Cells	\$1.1 M	Lift Truck
Plug Power, Inc. (1)	\$3.4 M	CHP
Plug Power, Inc. (2)	\$2.7 M	Back-up Power
Univ. of N. Florida	\$2.5 M	Portable
ReliOn, Inc.	\$8.5 M	Back-up Power
Sprint Nextel	\$7.3 M	Back-up Power
Sysco of Houston	\$1.2 M	Lift Truck

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Map of the United States showing the locations of Market Transformation and American Reinvestment and Recovery Act projects. The map includes state names and major cities. A legend in the bottom right corner identifies the pin colors: blue for Market Transformation and red for American Reinvestment and Recovery Act.

- Market Transformation (Blue pins)
- American Reinvestment and Recovery Act (Red pins)

15 | Fuel Cell Technologies Program **Source: US DOE 10/2010**

## Department of Defense

### Coordination

- Interagency Task Force
- Interagency Action Plan
- Interagency Working Group
- DOD/DOE MOU- LOU
  - Aviation APUs Workshop (completed)
  - Waste-to-Energy Workshop (1/13/11)
  - Shipboard APUs Workshop (TBD)
- Hawaii Hydrogen Initiative (H2I)
  - Commitment by industry, academia, and government to integrate hydrogen into Hawaii's sustainable energy plans

### Deployments

- Over 30 DOD sites with fuel cells providing back up & primary power
- Deployment of H2ICE buses at Hickam, AFB Honolulu, HI
- Continue exploring new applications

## DOD

- Defense Logistics Agency
  - 50 additional MHE units (on top of 40 current units) at Susquehanna, PA depot
- Office of Naval Research
  - Utility scale renewable hydrogen generation & H2ICE shuttle buses
- Army CERL
  - Backup power, waste-to-energy, and H2ICE shuttle buses

## Other Agency Coordination

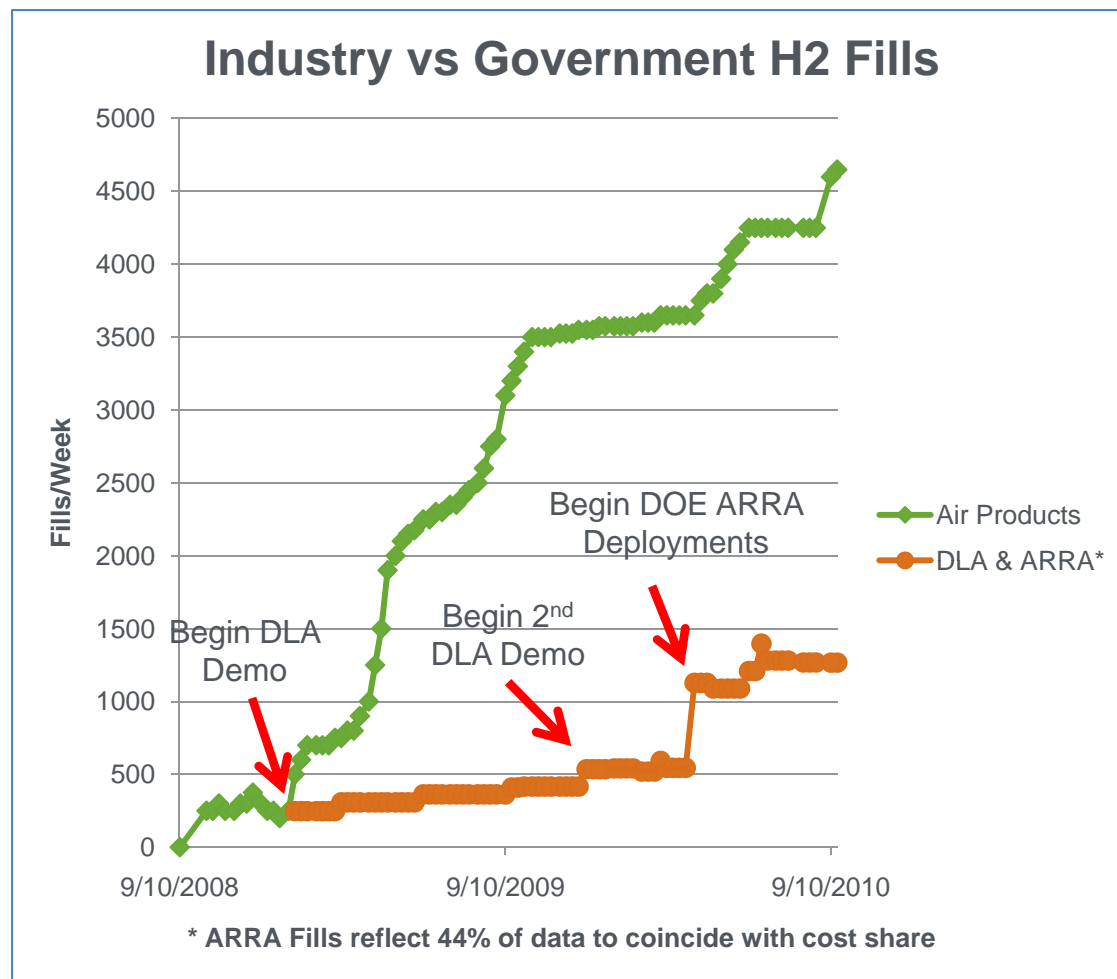
- Federal Aviation Administration
  - Ground support equipment & backup power
- National Park Service
  - Renewably generated backup power and H2ICE buses
- NASA
  - 5kW fuel cells for back up power
- USPS
- National Laboratories

Source: US DOE 1/2011

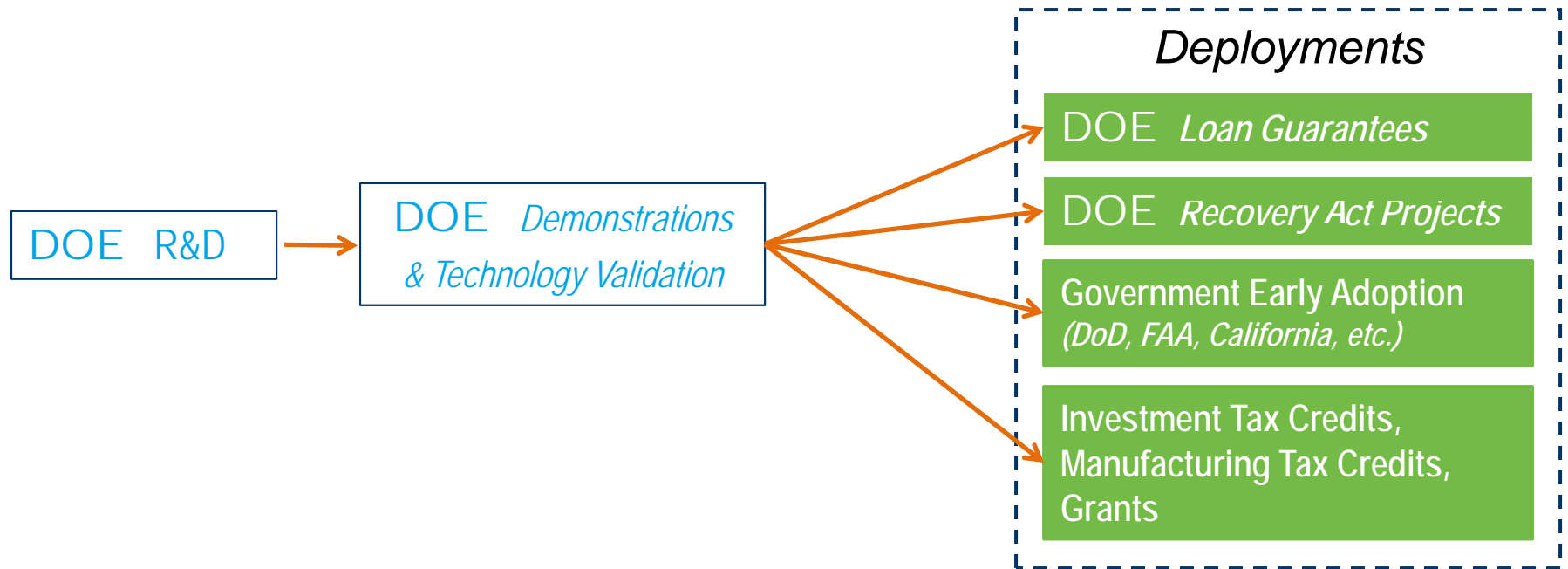


## Emerging Market Example

- Early Defense Logistics Agency (DLA) Procurement helped drive market development
  - From 250 fills/week to over 4500 fills/week
- Today's market is increasingly being driven by commercial demand
  - HEB, Whole Foods, Coca Cola, Sysco, Nestle, FedEx, BMW, etc
- DLA Demonstrations helped enable Codes and Standard approval of indoor Hydrogen dispensing



# Example of RD&D to Deployments



## Examples of Program

- Reduced high volume cost of transportation PEM Fuel Cells by 30% since 2008 and 80% since 2002
- Demonstrated double durability (>75,000 miles)

***What more can Government do to  
accelerate commercialization?***



***On October 5, 2009  
President Obama signed  
Executive Order 13514 –  
Federal Leadership in  
Environmental, Energy, and  
Economic Performance***

## ■ Requires Agencies to:

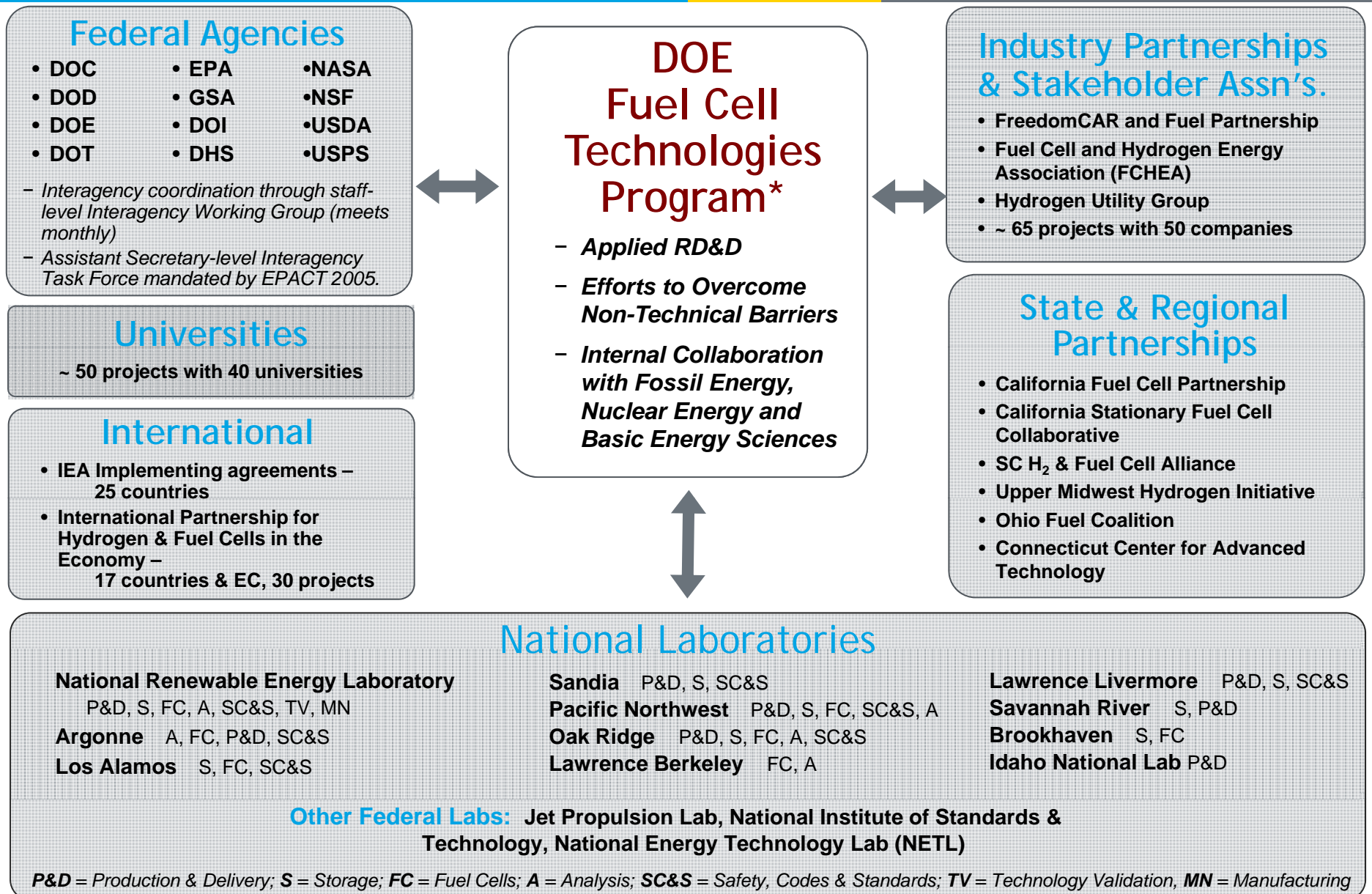
- Set GHG reduction Targets
- Develop Strategic Sustainability Plans and provide in concert with budget submissions
- Conduct bottom up Scope 1, 2 and 3 baselines
- Track performance

## Examples:

- Achieve 30% reduction in vehicle fleet petroleum use by 2020
- Requires 15% of buildings meet the *Guiding Principles for High Performance and Sustainable Buildings* by 2015
- Design all new Federal buildings which begin the planning process by 2020 to achieve zero-net energy by 2030

Potential opportunities for fuel cells and other clean energy technologies....

# Collaborations





# Examples of DOE-funded Partners and Locations – Fuel Cell Technologies Program



# Thank you

For more information, please contact

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